TECHNICAL MEMORANDUM (NASA) 74

RESULTS OF A LORAN-C FLIGHT TEST USING AN ABSOLUTE DATA REFERENCE

The results of a flight test using the Loran-C receiver and data collection system developed at Ohio University are described in this paper. An absolute data reference was provided by the Lincoln Laboratories DABS (Discrete Address Beacon System) facility.

by

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(NASA-CR-162751) RESULTS OF A LORAN-C FLIGHT TEST USING AN ABSOLUTE DATA REFERENCE (Ohio Univ.) 22 p HC A02/MF A01 CSCL 17G

N80-16051

Unclas
G3/04 47135

January 1980

Supported by

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

Grant NGR 36-009-017

I. INTRODUCTION

A closed circuit flight test was conducted on June 18 and 19, 1979 in the Boston area using VORs and NDBs as reference points. The Loran-C data collected during the flight was then compared against a reference provided by the Discrete Address Beacon System (DABS) facility at Lincoln Laboratories. This flight was a cooperative venture with the Massachusetts Institute of Technology. The MIT crew used a commercial receiver and recorded Loran-C time differences which would also be compared with the data provided by the DABS facility and eventually with the data collected by Ohio University.

The Ohio University low-cost receiver [1] [2] was used for this test which was conducted in the Ohio University DC-3 flying laboratory. The Loran-C time-difference data was recorded with a microcomputer data collection system and stored on magnetic tape for subsequent analysis. The MIT receiver was also on board the DC-3, and recorded its data on a cassette tape which was later used by the MIT crew for data analysis.

This paper presents information on the equipment configuration in the aircraft, the flight procedure and the results obtained from the data collected with Ohio University's receiver and recording system.

II. DISCUSSION

The flight test was planned for June 18 and 19, 1979 in the Boston area. Ohio University's DC-3 Flying Laboratory N7AP was used for this test. The flight was conducted using Victor airways and VOR navigation during the flight from Athens to Boston. Figure 1 shows a flight plan used by the crew responsible for the data collection and shows the VORs along the route, their latitude and longitude and the expected time differences over these VORs. This was used by the crew to insure that the data collection system was tracking correctly, and also was used as a reference for entering event marks on the data tape.

The actual flight test was conducted by flying a closed circuit in the Boston area with the data collection system in operation. An absolute reference was provided by the DABS radar facility at the Lincoln Laboratories. The data collected for this test then consisted of a tape containing the time differences recorded by the data collection system and a tape recorded by the DABS computer containing range and azimuth information relative to the DABS facility. The flight path was chosen to include several land references which would be noted on the data tape for later analysis; the flight path is shown in Figure 2.

The ADF sense antenna on the DC-3 was used in the Loran-C experiment along with a special preamplifier developed by Burhans. [3] This preamplifier contains filters to help minimize interference from broadcast band and other signals at frequencies above Loran-C. This preamplifier also contains outputs to drive several receivers and was used for both Ohio University's receiver and MIT's receiver. A block diagram of the data collection system as installed on the DC-3 is shown in Figure 3.

U.S. NORTHEAST CHAIN 99600

VORTAC	LATITUDE			LONGITUDE			W	X	Y	Z
PKB	39°	26'	28"	81°	22'	30"	16588.50	28508.72	42704.69	57159.06
IHD	39°	58'	27"	79°	21'	31"	16550.57	28423.10	43215.58	58243.96
JST	40°	19'	00"	78°	50'	04"	16542.46	28438.35	43504.49	58580.39
TON	40°	44'	06"	78°	19'	54"	16538.50	28479.05	43852.42	58935.59
PSB	40°	54'	58"	77°	59'	35"	16526.29	28480.07	44020.10	59139.67
IPT	41°	20'	19"	76°	46'	31"	16400.51	28360.23	44428.13	59726.56
LHY	41°	28'	33"	75°	28'	59"	16030.45	27919.42	44469.48	60010.74
PWL	41°	46'	11"	73°	36'	04"	15244.73	27042.65	44389.41	60178.07
BAF	42°	09'	43"	72°	43'	00"	14791.26	26655.08	44437.87	60245.15
GDM	42°	32'	45"	72°	03'	31"	14412.18	26412.71	44491.10	60283.00
BOS	42°	21'	28"	70°	59'	38"	14032.40	25862.50	44294.04	60267.28

ALBANY TO BOSTON VOR CHECKPOINTS

Figure 1. Checkpoints for Trip to Boston and Trip from Boston.

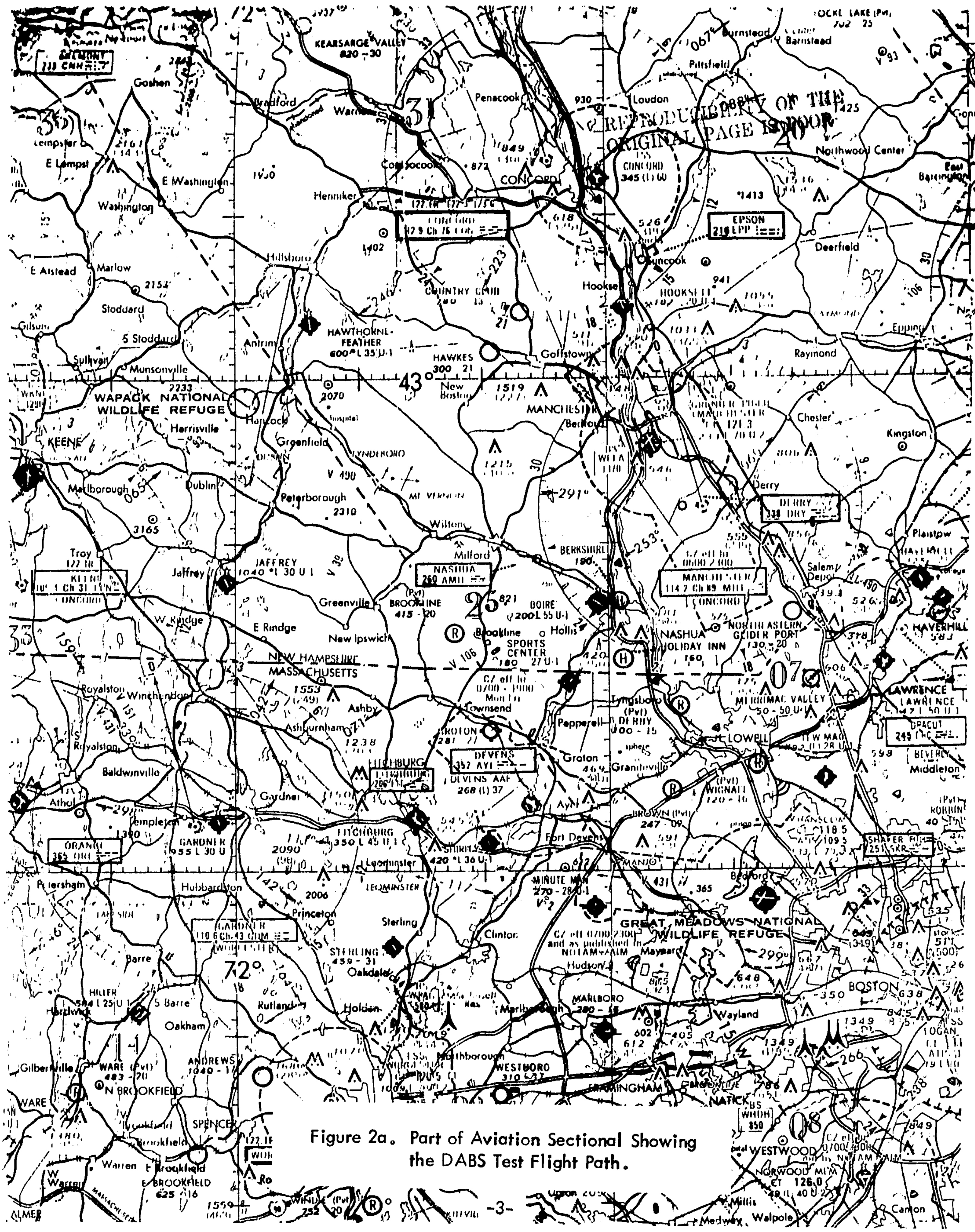

Figure 2a. Part of Aviation Sectional Showing the DABS Test Flight Path.

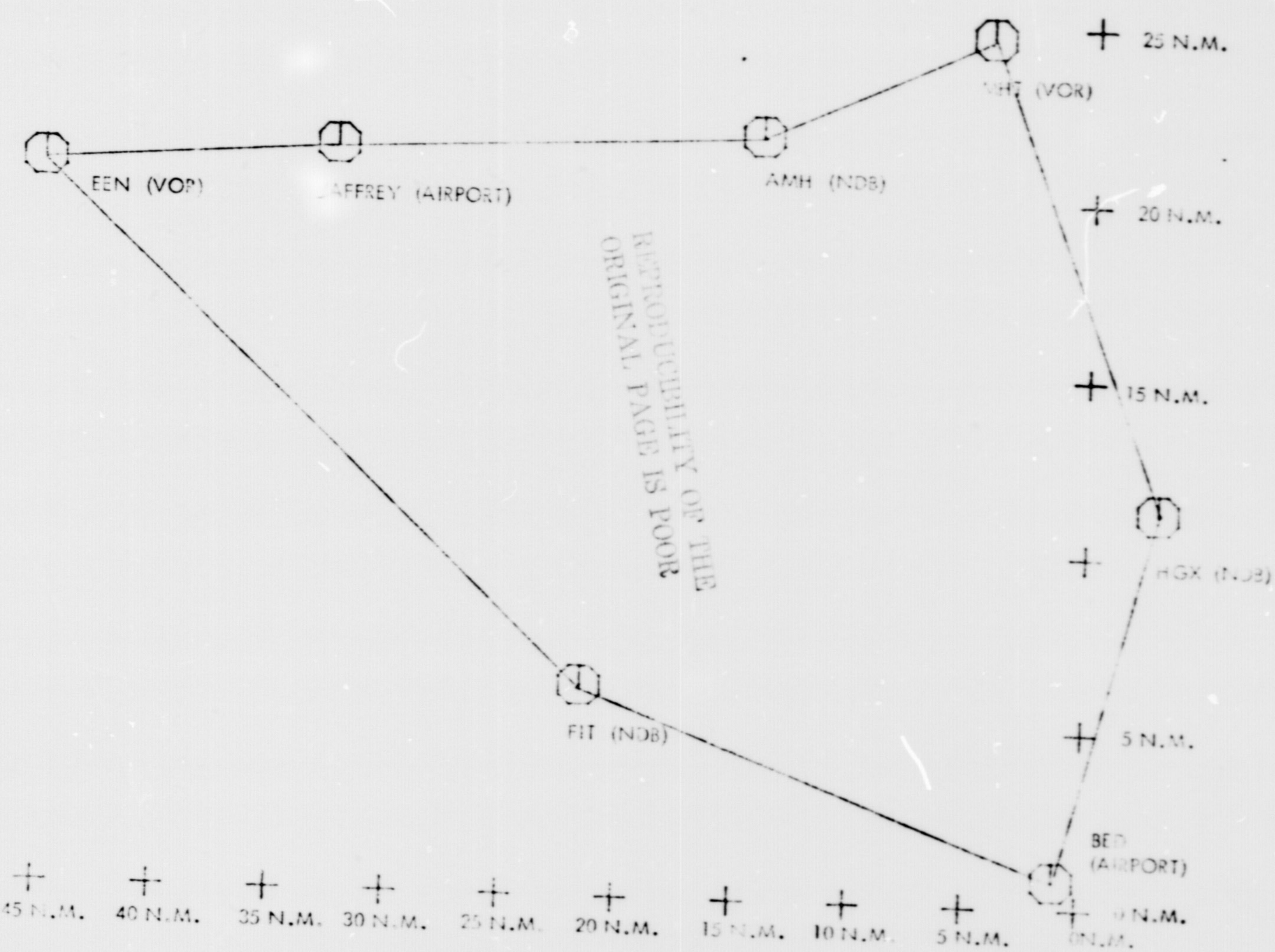

Figure 2b. DABS Test Flight Path Using Plotting Scale for Succeeding Data Plots.

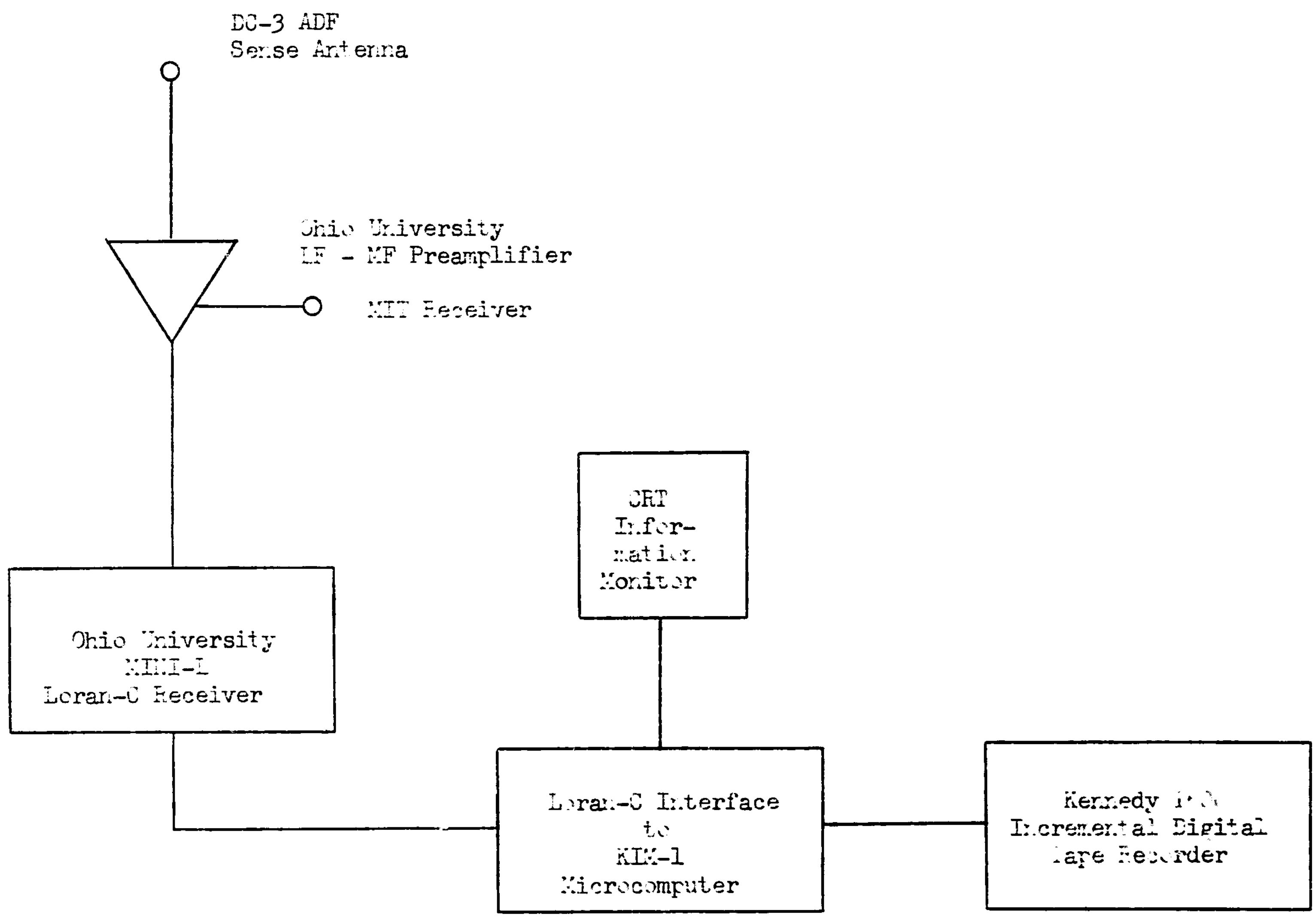

Figure 3. Flight Test Equipment Configuration.

The U. S. East Coast Loran-C chain, 99600, was used in this flight test with Seneca, N.Y. as the master and Caribou, Maine (W) as the first secondary and Nantucket (X) as the second secondary station.

III. POST-FLIGHT PROCESSING AND RESULTS

All data recorded by the microcomputer consisted of GRI index numbers and the time differences for the two station pairs. The GRI index is initialized to zero at the start of the flight test and is incremented by one each time a Loran-C group repetition pulse is received, or equivalently, the index is incremented upon receiving the master pulses. By this method, each data point may be noted as being received at some time after the data recording operation began. All the TDs recorded are raw data, i.e., no averaging or smoothing was applied by the micro-program. In subsequent post-processing done on the main computing facility, no filtering was done; all plots shown in this paper are the raw data received and show rather good stability. Since the recorded data is in time-difference format, post-processing included the conversion of the TDs to latitude/longitude and also rho/theta (range-azimuth) relative to the DABS facility. Post-processing was conducted on the Ohio University IBM System/370 computer using procedures described in a previous report. [4]

The Loran-C flight test data was recorded on magnetic tape using the Kennedy 1600 digital recorder. The data was separated into three separate files: the flight to Boston, the flight test with the DABS facility, and the return flight to Athens. The unformatted data from the microcomputer was first converted to a more convenient format and stored on a second tape volume; following this, the data was scanned for bad data points and converted to lat/long and rho/theta which was stored on a disk volume for plotting.

For the discussion on the plotted results to follow, it should be noted that the scale for each plot is the same. The tick mark nearest the point marked "BED" is the location of the DABS radar facility and represents the origin. Each tick mark to the left of the origin is five nautical miles in the west direction; each tick mark above the origin is five nautical miles in the north direction. The rho/theta information obtained from the data reduction job is plotted on this scale with each point being the distance in nautical miles and bearing in degrees from the DABS facility. The data obtained from the DABS tape was already in rho/theta format; no post-flight filtering was applied to the DABS data.

Figure 4 is a plot of the DABS data for the first test pass on the 18th. This shows the flight path starting at the airport and continuing out in a counter-clockwise direction, then circling and landing at the airport. Some jitter in the data can be noted at the farthest distance (near Keene) and can be attributed to the few hits made by the radar at this far range. Figure 5 is a plot of the raw data collected by the microcomputer. Here it may be noted that the plot follows nearly the DABS track but seems to exhibit a bias of approximately one nautical mile. This will be explained later. Much of this flight path was done in a thunderstorm and the receiver lost lock temporarily due to lightning static as evidenced by the broken plot near the Fitchburg NDB. The data shows good consistency even though the receiver was operating in an unusually high noisy environment. This first flight pass wa

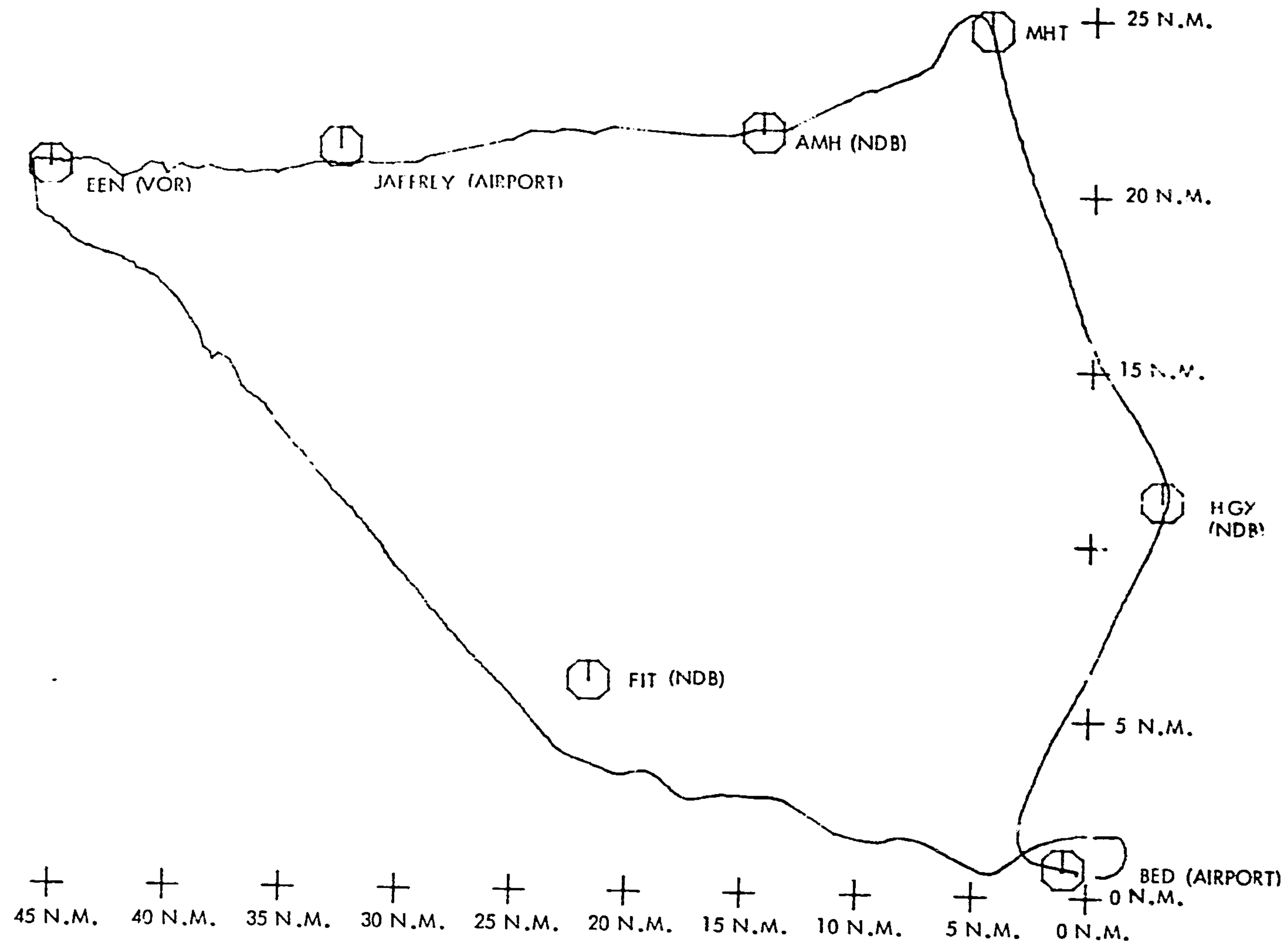

Figure 4. DABS Data Plot for Flight Test on June 18.

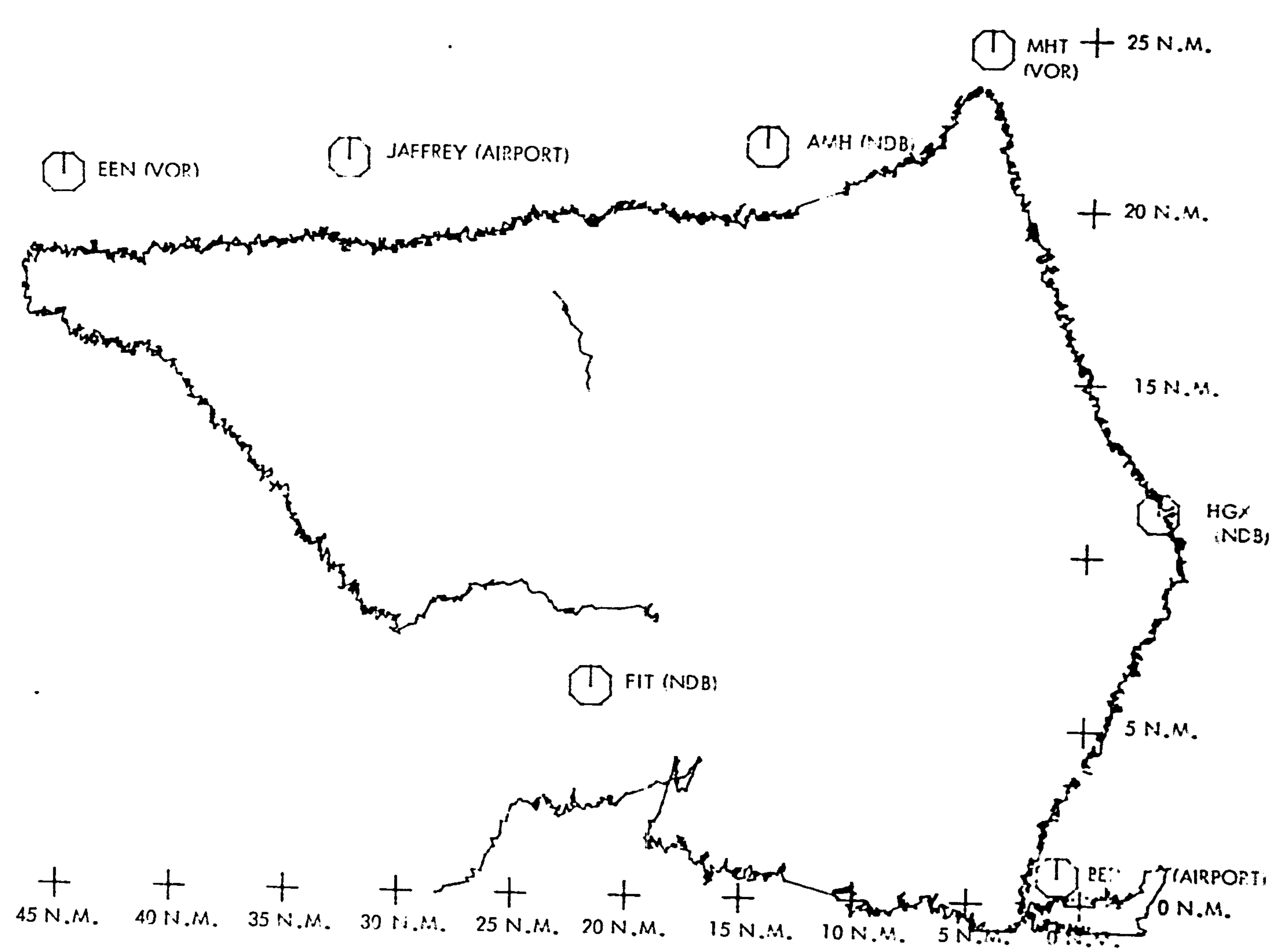

Figure 5. Microcomputer Data Plot for Flight Test on June 18.

designed mainly to serve as a preliminary trial to insure that all systems would work correctly for the next day's tests.

The tests made on the next day (June 19) were in good weather conditions allowing the VORs and NDBs used as events marks to be spotted visually in most instances. A power supply problem developed during the flight test and caused the data collection system to fail several times, after which it was then necessary to reload the control program. This also caused the data collection tape to have several blank gaps in it which subsequently caused a great deal of trouble in recovering the data during the data reduction process. As a result, all of one flight circuit was lost and half of another was lost. However, enough data was recovered for useful analysis.

Figure 6 is a plot of the DABS data for the second pass on the second day (June 19). Again, some jitter is evident at the farthest point due to the conditions discussed earlier. Some other small glitches can be seen in these DABS plots which are due mainly to changes entered in the DABS computer for tape changes, and ATC transponder code changes. Figure 7 is the corresponding plot of the data collected by the microcomputer for the second pass. Much of the data is missing because of the power problem already mentioned. As with the previous microcomputer plot, this is raw data and the data is fairly stable, although the southward bias is evident.

The last pass made on the second day was made in the reverse direction, i.e., in a clockwise direction. Figure 8 is a plot of the DABS data for this pass, and the microcomputer data is shown in Figure 9. The microcomputer data is quite stable as can be seen in this plot.

In all the microcomputer plots shown up to this point, the data appears to have a fixed bias to the south. After analysis of the plots and printed listings, it was found that the microcomputer plots could be made to correspond more exactly to the DABS plots by adding 18 microseconds to the second TD number (Nantucket). Upon further checking, it was noted that the Nantucket secondary Loran-C station is approximately 100 miles from the Boston area and provides a very strong signal, particularly while in the air. It was then decided that such a strong signal was overloading the envelope processor in the front-end of the test-flight receiver. A study has been made into the effect of various signal and noise levels on the receiver and has been reported by McCall. [5] Further studies on envelope processing and front-end processing is ongoing.

Figures 10, 11, and 12 show the microcomputer data plotted with the 18 microsecond offset added for the first pass on June 18, the second pass on June 19, and the last pass on June 19, respectively. It can be seen that the microcomputer data follows the flight path to a much greater extent. Simultaneous plots of the DABS data with the microcomputer data for the three flight test passes are shown in Figures 13, 14, and 15. It should be noted that some of the DABS data is missing in these plots near the Keene VOR because of the far distance from the radar involved and also because the aircraft flew below the minimum altitude the radar requires for good accuracy at this distance.

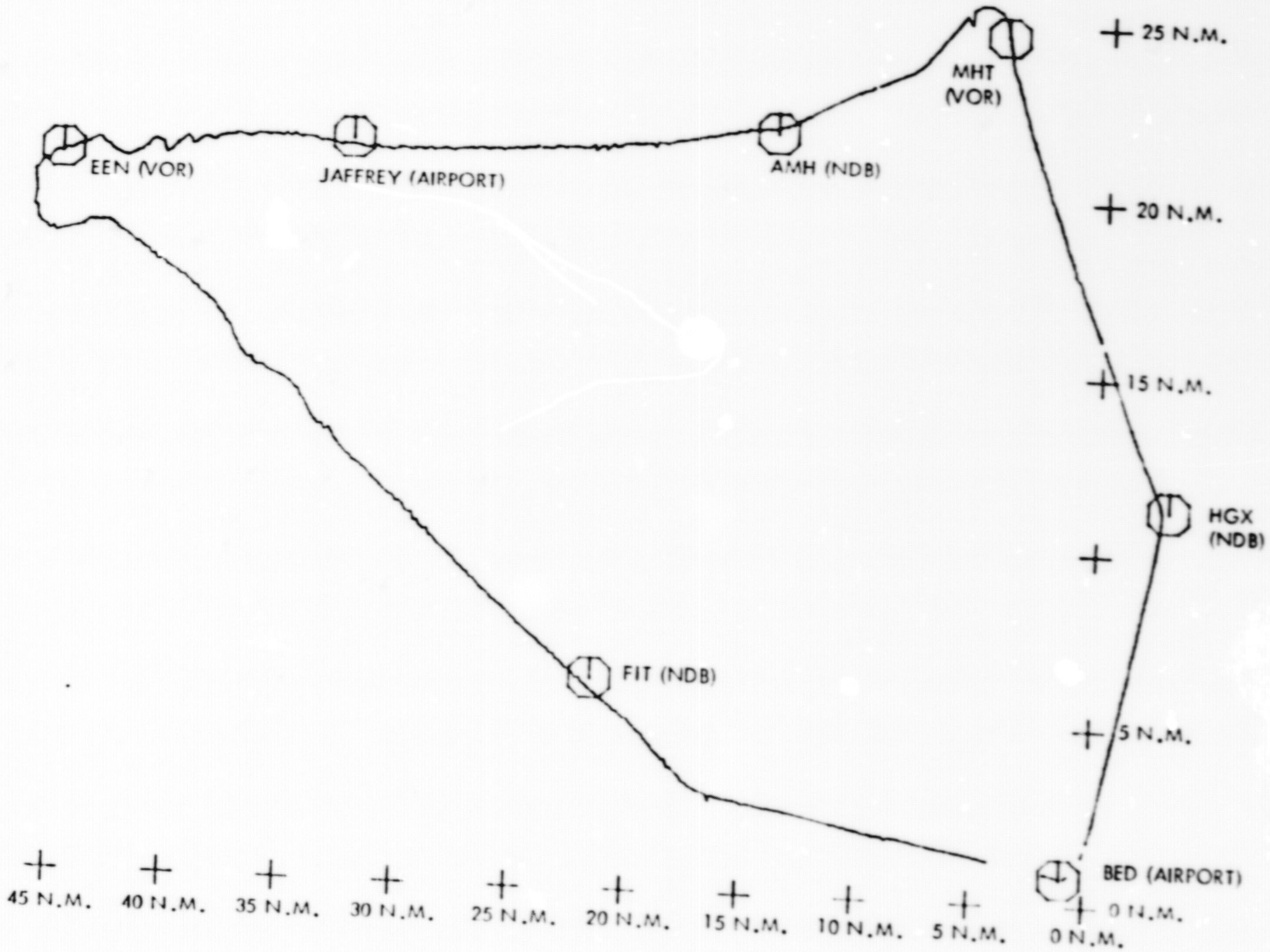

Figure 6. DABS Data Plot for Second Flight Pass on June 19.

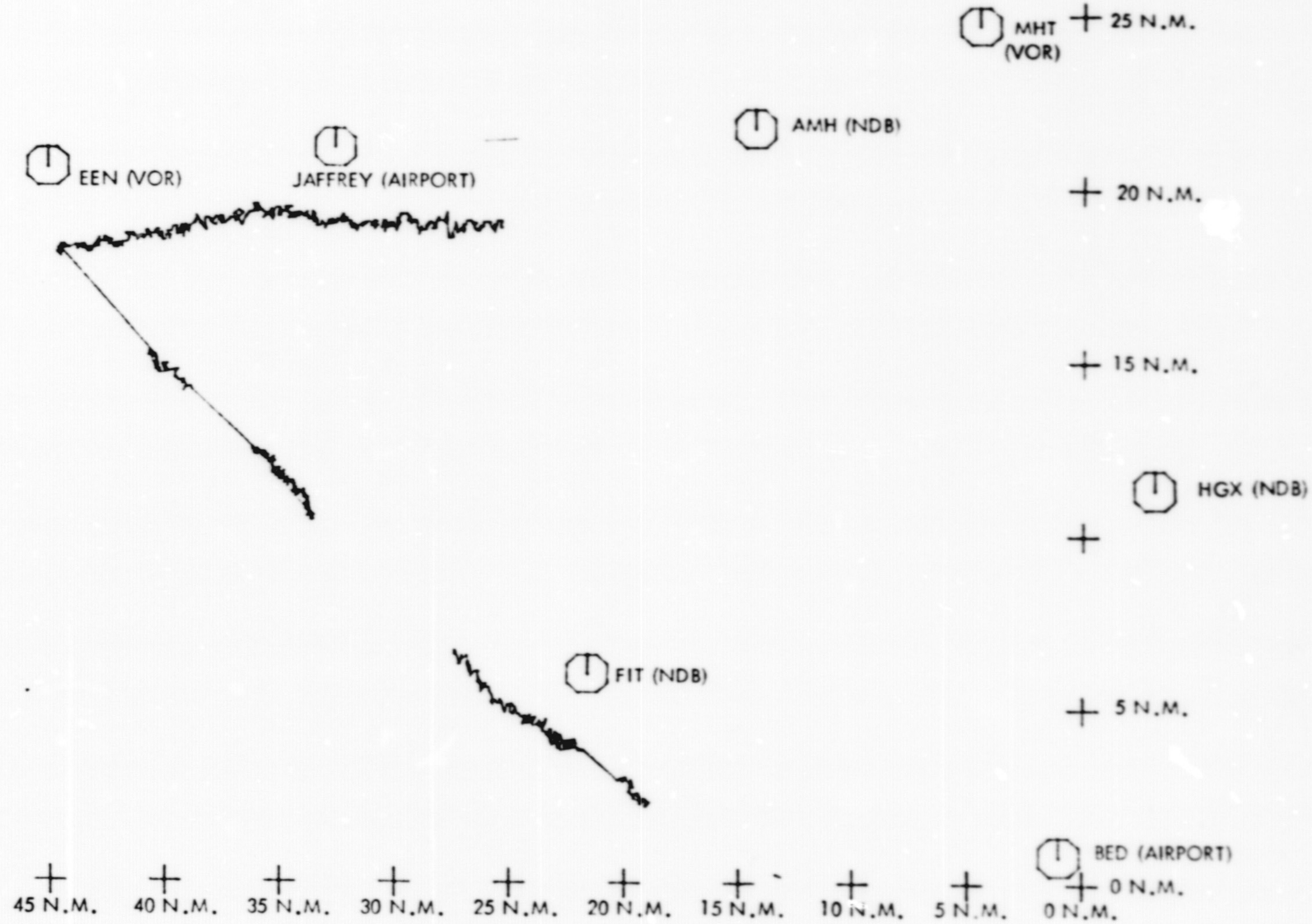

Figure 7. Microcomputer Data Plot for Second Flight Pass on June 19.

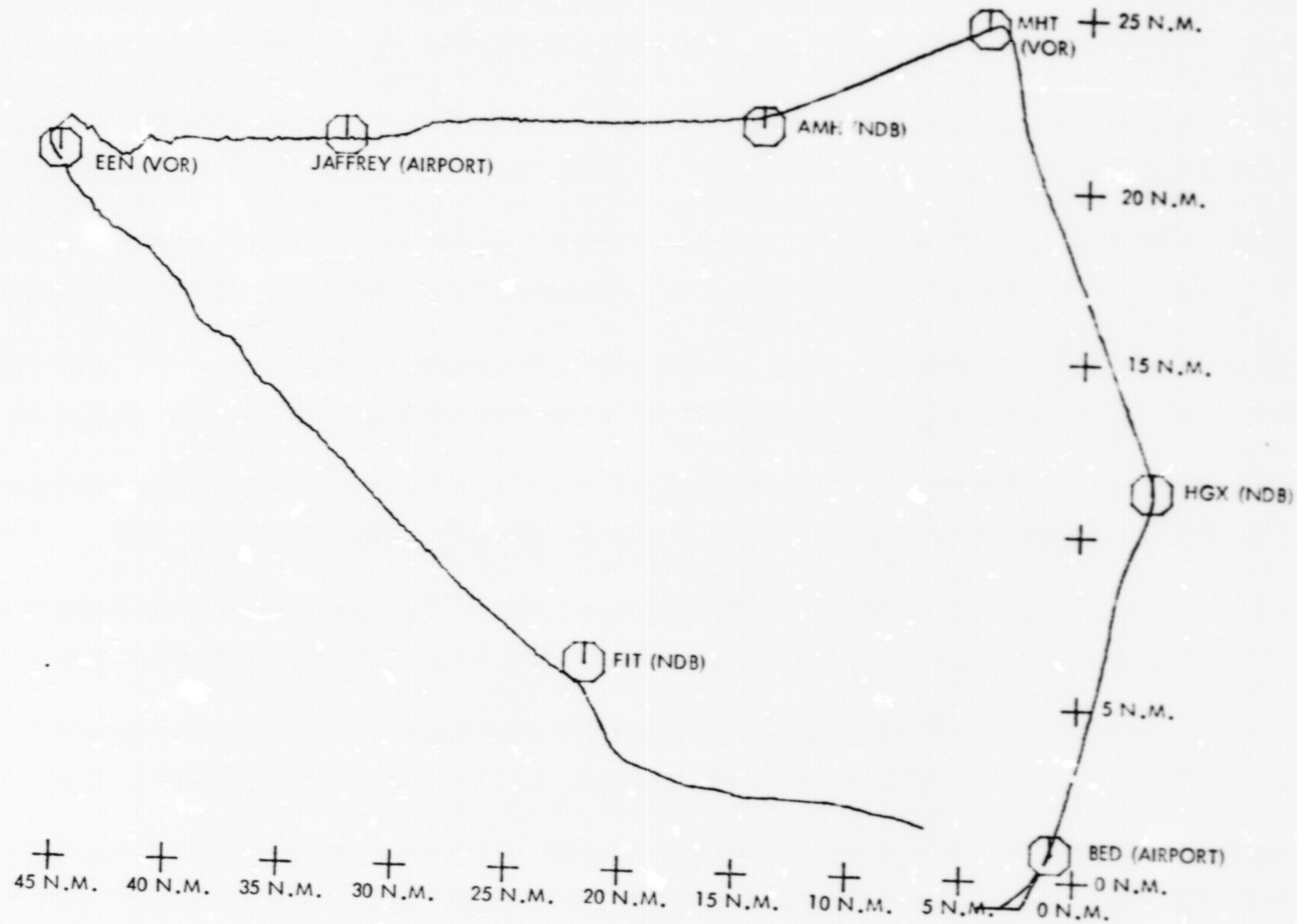

Figure 8. DABS Data Plot for Third (Last) Flight Pass on June 19.

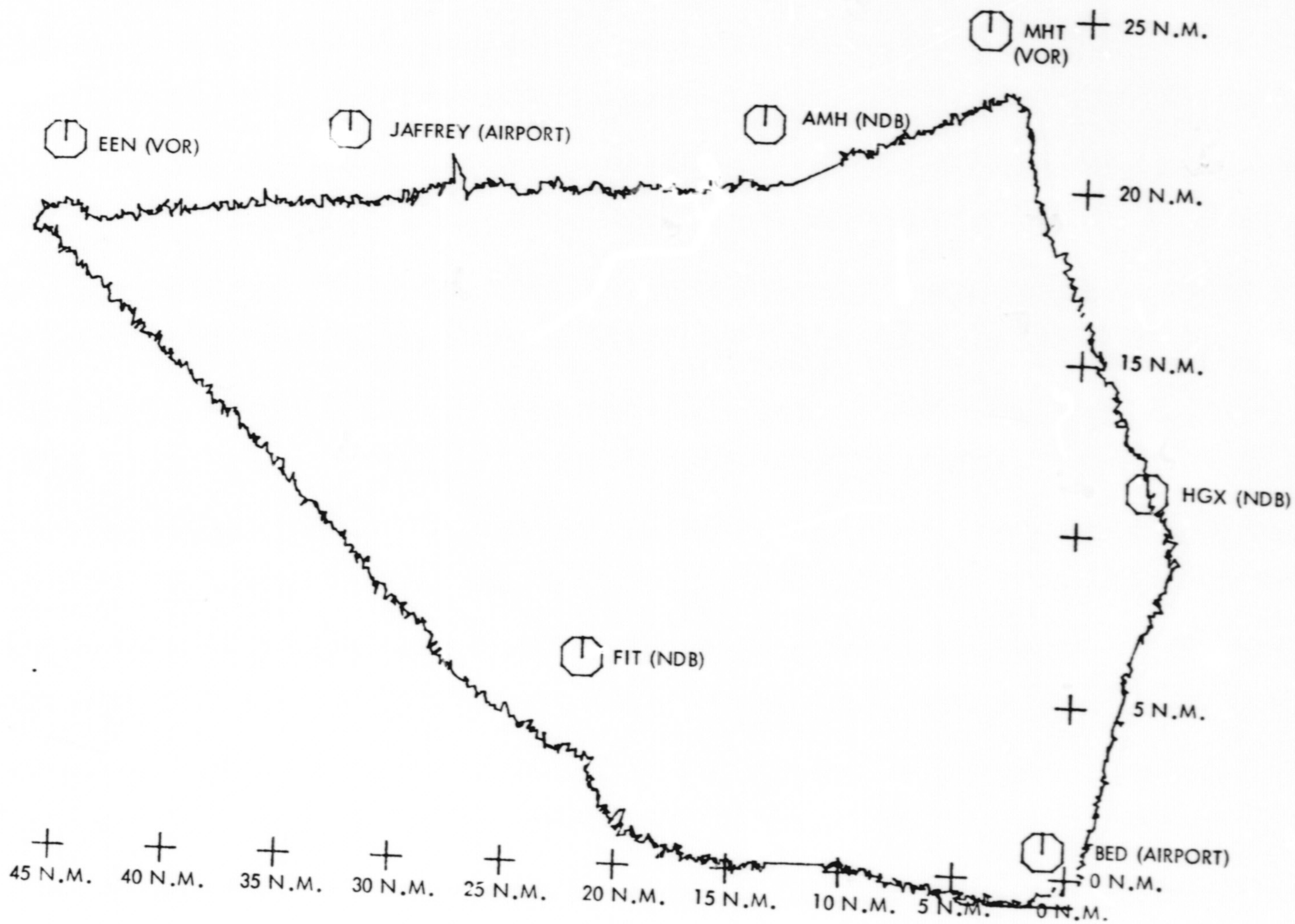

Figure 9. Microcomputer Data Plot for Third (Last) Flight Pass on June 19.

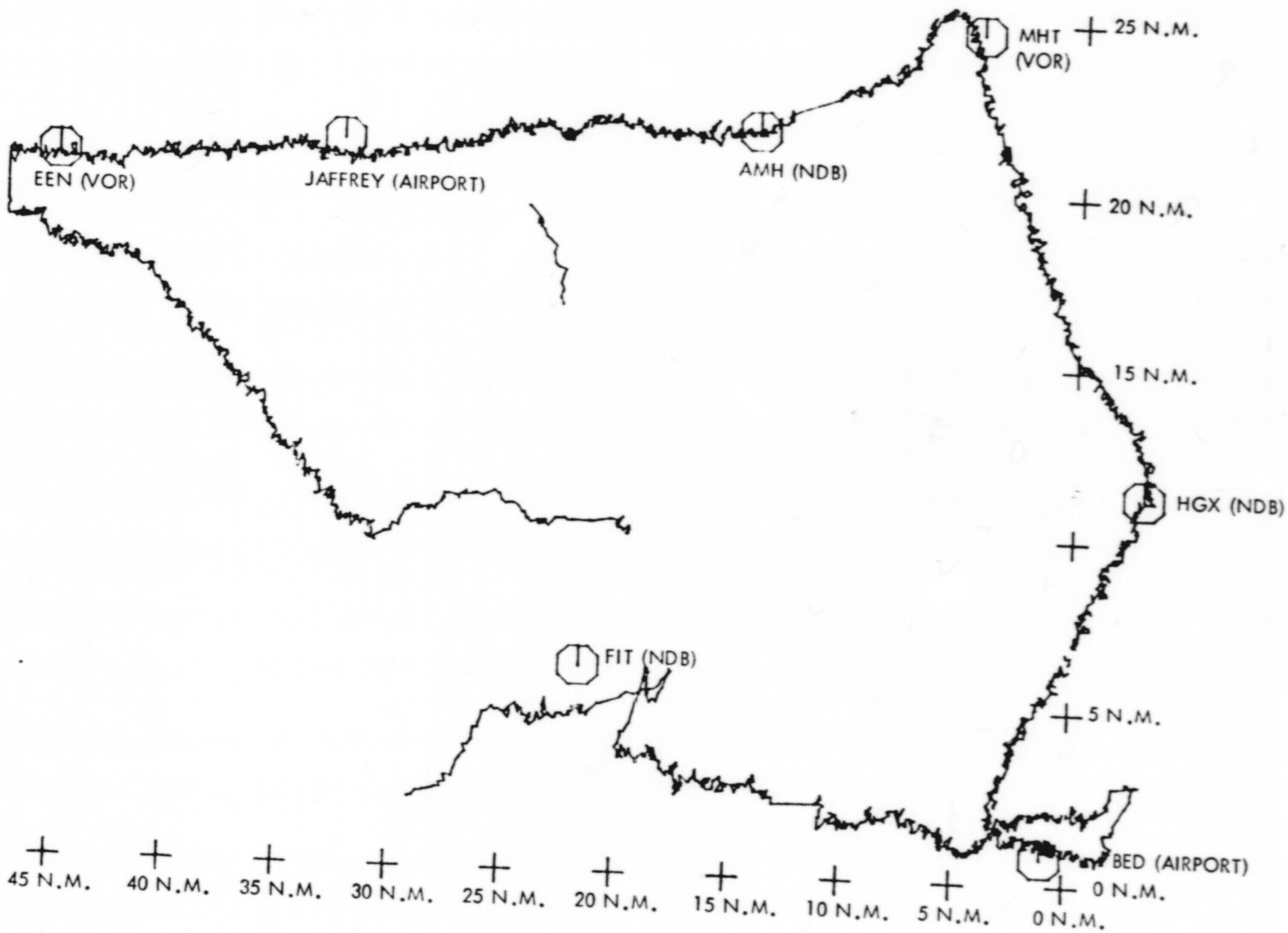

Figure 10. Microcompute ata Plot of Flight Test on June 18 with 18 us. Offset Added to Pair X.

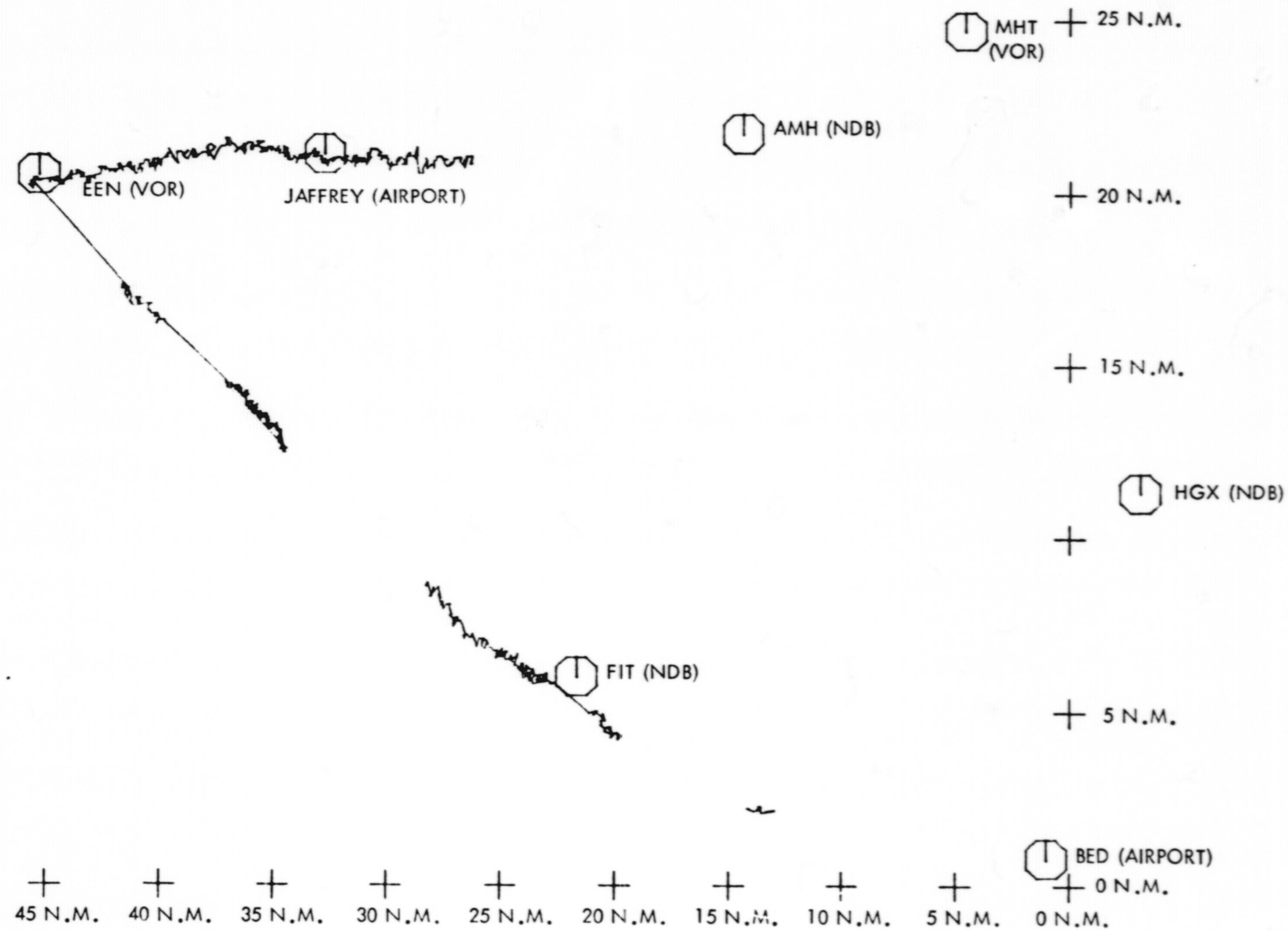

Figure 11. Microcomputer Data Plot of Second Pass on June 19 with 18 us. Offset Added to Pair X.

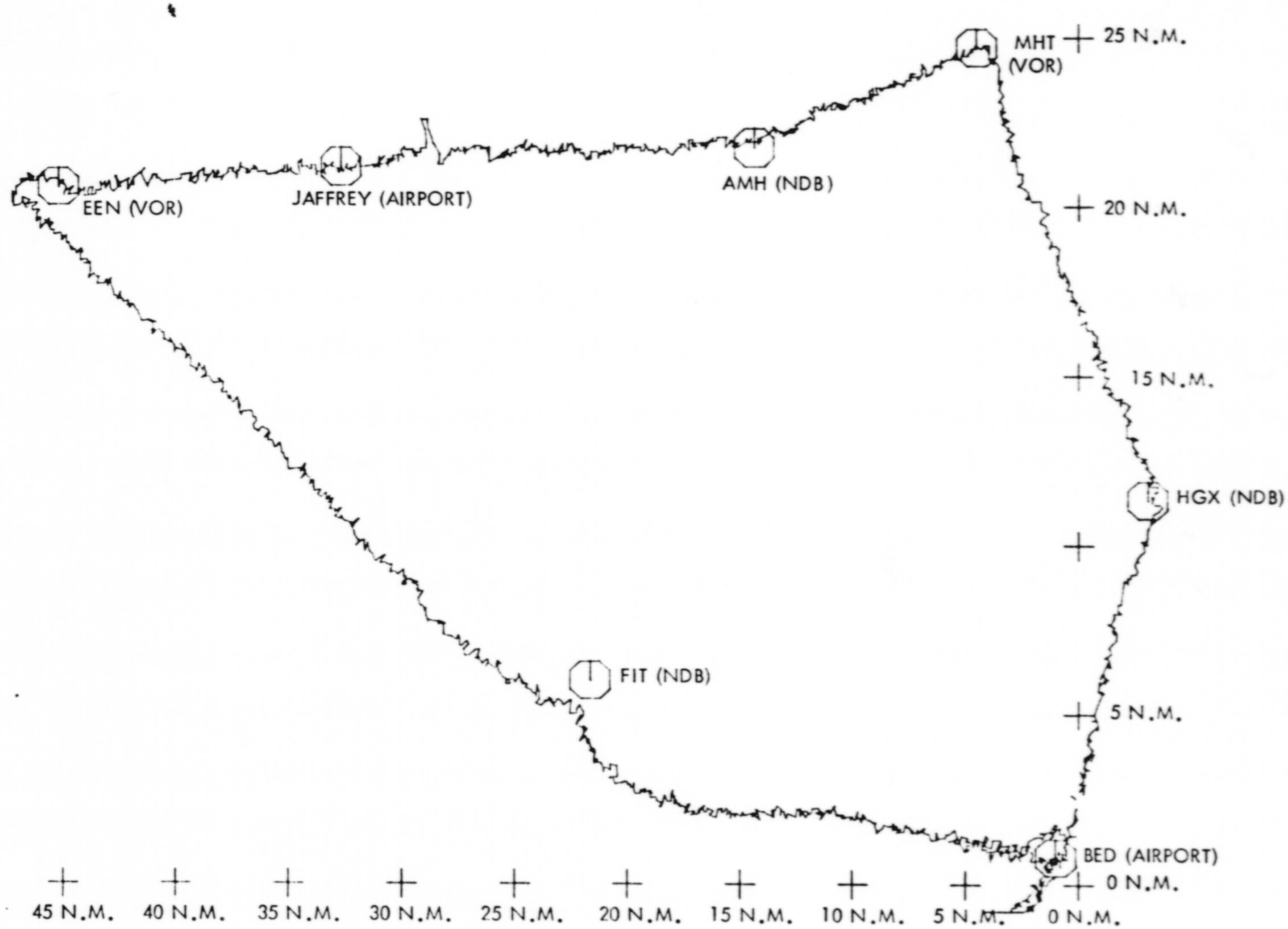

Figure 12. Microcomputer Data Plot of Third Pass on June 19 with 18 us. Offset Added to Pair X.

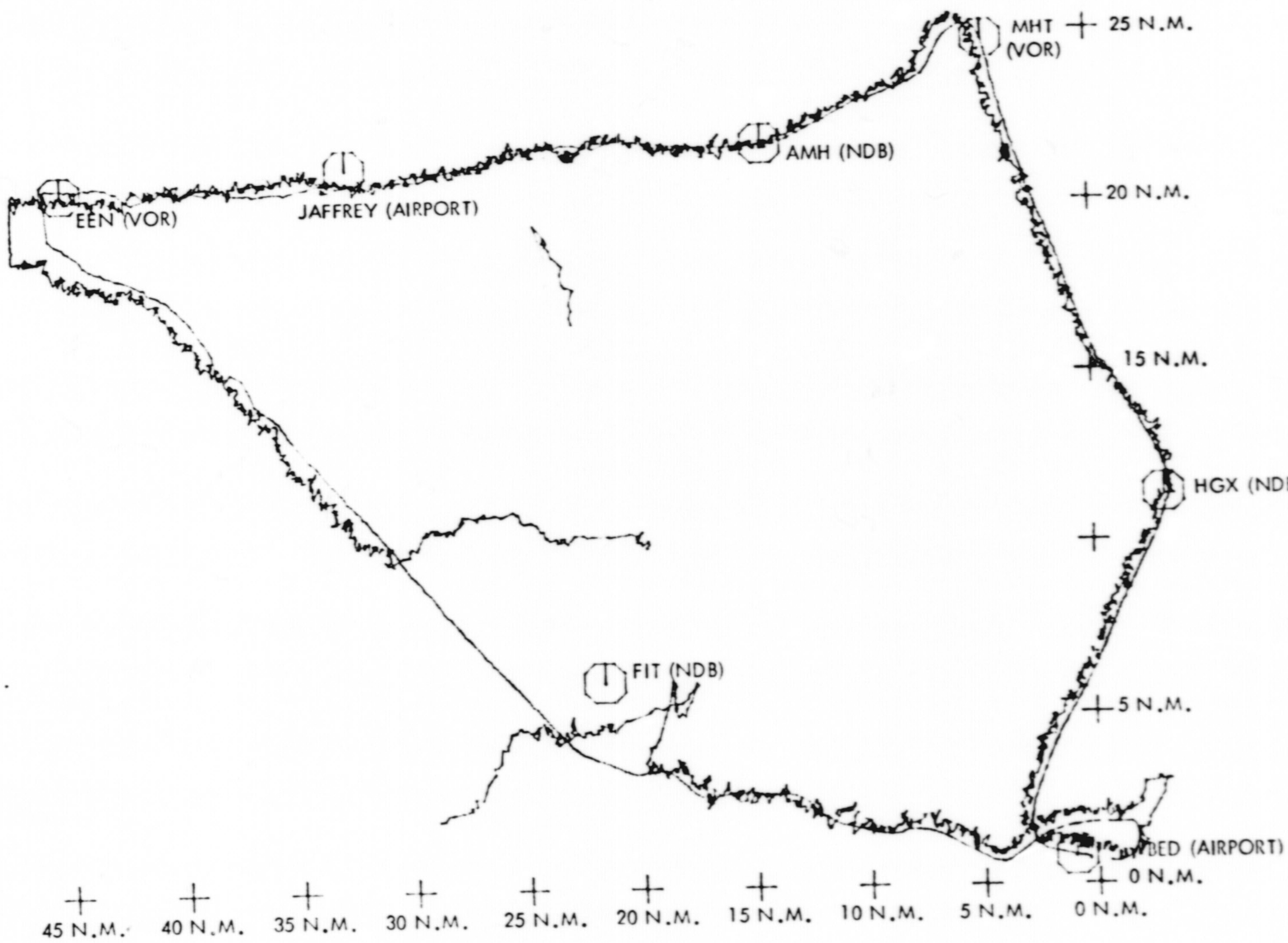

Figure 13. Combined Data Plots of DABS and Microcomputer Data for June 18, with 18 us. Offset Added.

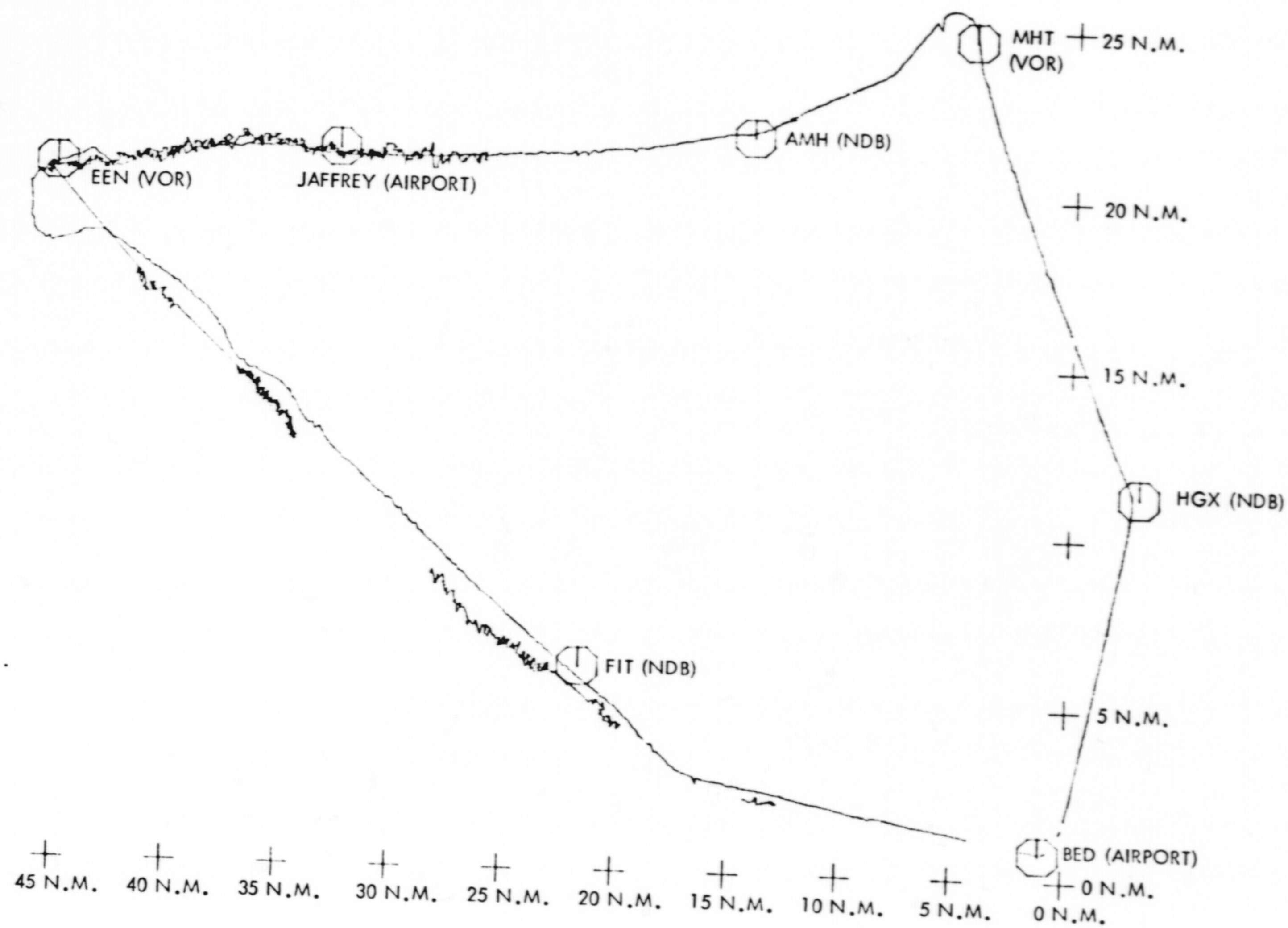

Figure 14. Combined Data Plots of DABS and Microcomputer Data for Second Pass, June 19, with 18 us. Offset.

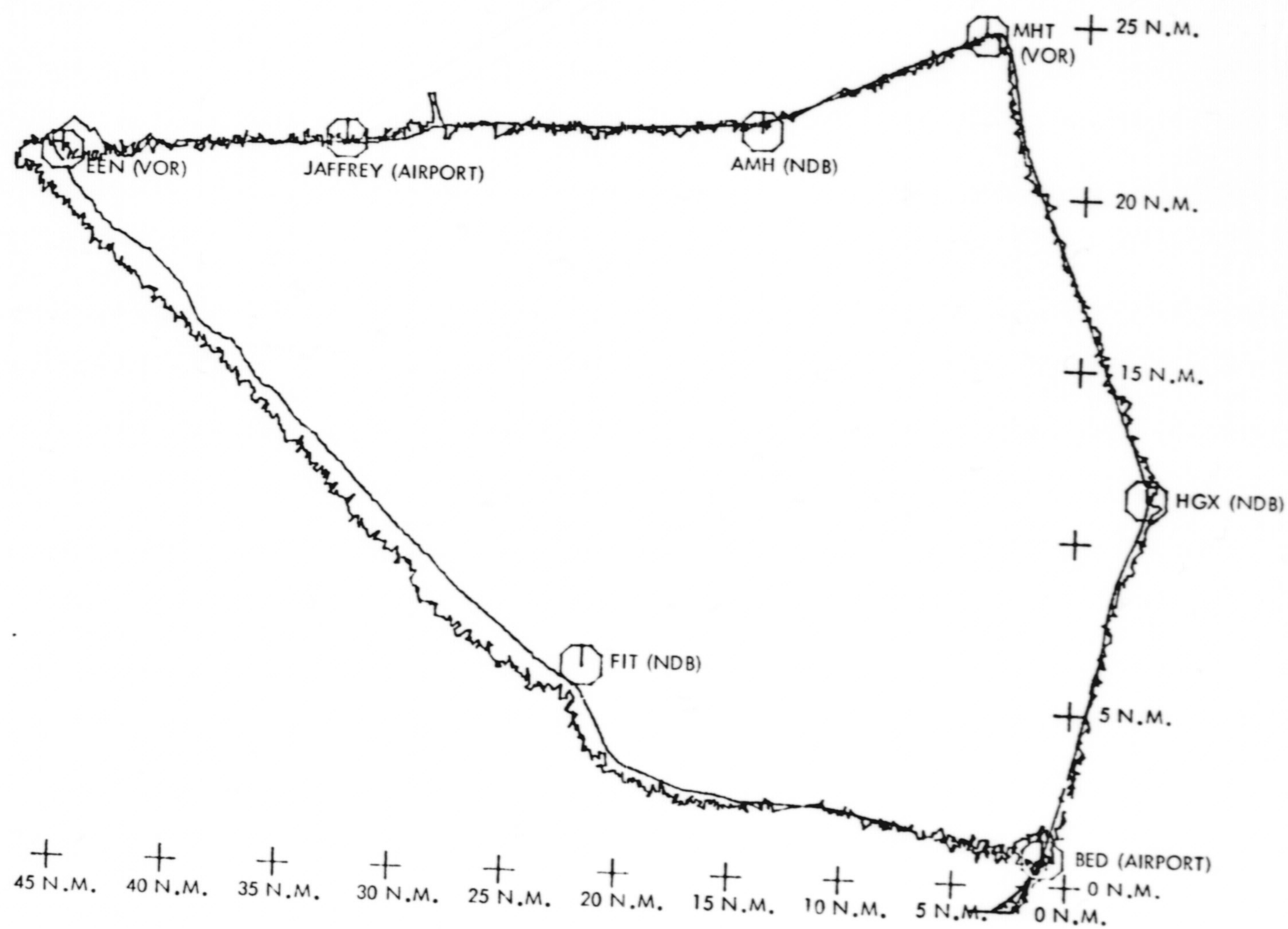

Figure 15. Combined Data Plots of DABS and Microcomputer Data for Third Pass, June 19, with 18 us. Offset.

IV. SUMMARY

The opportunity to conduct a flight test with an absolute reference was valuable in that it allowed a more detailed analysis of the performance of the Loran-C receiver. Although a definite bias was found in the data, the stability and repeatability of the receiver was very good. The results of this test will be an aid to further development of front-end processors for low-cost Loran-C receivers.

Several factors for future work came out of this flight test. These include: continued work on optimum antenna/preamplifier designs for use in conjunction with various receiving setups to minimize noise and overloading problems, evaluation of reliable power sources for the data collection equipment to eliminate power supply noise, and low voltage and voltage drop-out problems, and continued work on implementing coordinate conversion techniques for use on the microcomputer.

V. ACKNOWLEDGEMENTS

Much of the organization for this flight test was handled by Dr. R. H. McFarland, Director at Ohio University and Professors R. Simpson and W. Hollister, Project Directors at MIT. Other support was rendered by R.W. Burhans, Project Engineer at Ohio University and Mr. Carter Pfaelzer of MIT who were in charge of setting up the receivers and antenna/preamplifier systems; Mr. Daryl McCall of Ohio University and Mr. Allen Littlefield of MIT who were primarily responsible for the operation of the receivers during the flight test; and Mr. D.G. Pullins who was the co-pilot of the DC-3. General assistance in organizing the flight test and post-flight analysis was given by Dr. R. W. Lilley, project advisor at Ohio University. The personnel at the DABS facility were very helpful in organizing the radar data and clarifying some interpretations of the plots in this paper.

VI. REFERENCES

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